

Attainable Speed Limits: Effect of the Electrical and Heat Fields on the Photolysis of AgHal Systems

Yuri Breslav, Michael Ushomirsky, Boris Borshevsky, Anatoli Heinman
Russian Society of Photographic Science and Technology
Moscow, Russian Federation

Abstract

It is doubtful to expect the further AgHal systems speed enhance within the classic paradigm more than the achieved limits of 5-10 quanta per AgHal grain. One of the most effective methods to increase inherent and spectral sensitivities without deterioration of image quality is the exposure to external electrical and heat fields during the photolysis stage. Due to the optimization of several factors: impulse voltage and form, time-lag effect, sequence of the light and electrical field impulse, system temperature etc., the photographic response of ortho- and orthopanchromatic films can be increased by the factor of 10-100 at the same image quality.

Introduction

The mechanism and consequtive stage order of the photographic latent image formation are well-known. The long way of the sensitometric properties improvement resulted in the some new approaches to increase the photographic response, among them:

- electron multiplication by photoholes and mediators Ag_2 [1,2] or RCOOMe [3]
- cascade amplification in much the same way as a human visual perception [4]
- exposure to the external electrical and heat fields during the photolysis stage [5-7].

The numbers of publications have dedicated the effect of impulse electrical field on the photographic materials. There is a common opinion that the exposure to impulse elecrical field result in the significant increase of light sensitivity. Nevertheless the model emulsion layers, far from the optimum sensitometric properties, were studied. On the other hand, the form of electrical impulse, sequence of light exposure and electrical field impulse, time-lag effects etc. were not studied in details. Moreover the influence of electrical field on an image quality and signal / noise ratio have got out of the sight.

The given study represents an attempt to piece out the above void.

Experimental

Three types of photographic materials were taken for the trials: a – orthopanchromatic film (cubes, d=0.25μ, COV=15%, Speed Class ISO 200); b – orthopanchromatic film (cubes, d=0.20μ, COV=18%, Speed Class ISO 100) and c – orthochromatic film (T-grains, d=1.0μ, h=0.18μ, COV=17%, Speed Class 400).

The above films have been placed between two transparent glass plates-electrodes with the vacuum coated conducting layers.The optical contact between electrodes and surface of emulsion layers was created by the special medium.

The light exposure (2850 and 5000°K) was varied from 10^{-6} to 10^{-1} sec. During the light exposure photographic films were subjected to the action of impulse electrical field (IEF). The field voltage was $2.5x10^{6}$ V/cm for all trials, that is lower than the break-down voltage. The form of elecrical field impulse, moment of impulse switching on during the light exposure and system temperature were varied.

The IEF effect was estimated by the value ΔLog H = Log H_0 – Log H_f , where: Log H_0 and Log H_f are logarithms of light exposure necessary to attain the optical density equal $0.2+D_0$ without and with IEF, correspondingly.

Fig.1 shows the typical quasirectangular form of electrical field impulse and dependence of IEF effect on the retention time is illustrated in Fig. 2.

Type “+” impulse

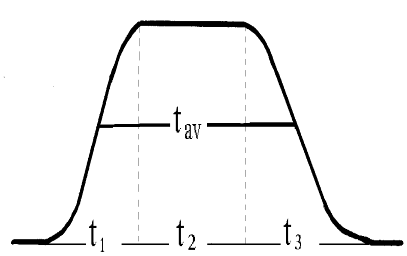

Figure 1. Quasirectangular form of electrical field impulse
t_1 – retention time of the impulse front
t_2 – impulse life
t_3 – drop time
t_{av} – average impulse cycle, $0.3x10^{-6}$ sec

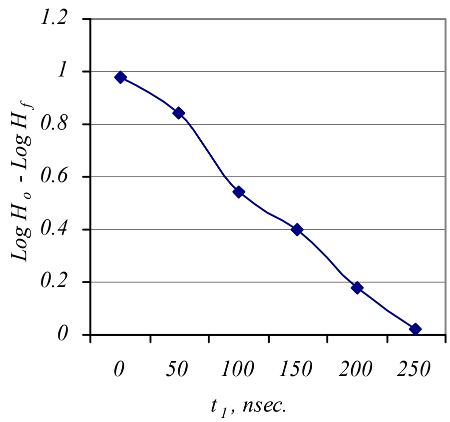

Figure 2. Effect of retention time (t_1) on the photographic response
Film: orthopanchromatic, cubes, d=0,20µ, E=2.5x10^{-6} V/cm type "+"impulse

The IEF effect depends on the time–lag (t_{t-1}) of electrical field impulse relative to the light impulse as shown in Fig. 3 and 4. The photographic response remains as maximum up to t_{t-1} equal $2x10^{-3}$ sec. and this value is the system memory time.

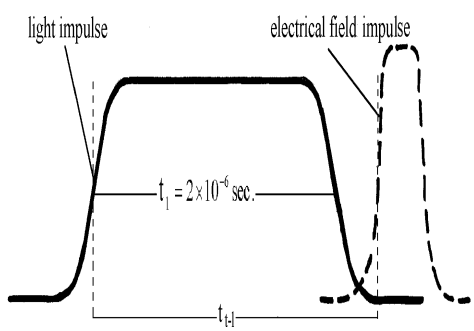

Figure 3. Sequence of light and electrical field impulse

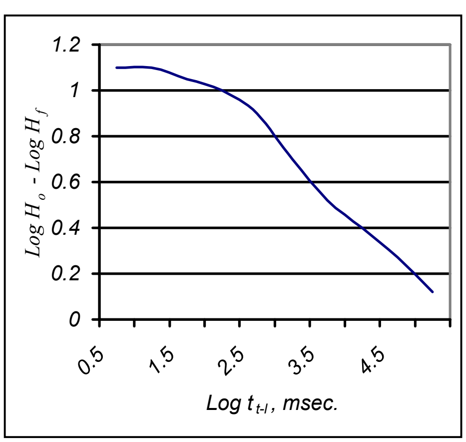

Figure 4. Time-lag effect of IEF on the photographic response

Film: orthopanchromatic, cubes, d=0,20µ, E=2.5x10^{-6} V/cm type "+"impulse

The significant rise of IEF effect was observed for the altering electrical field impulse (Fig.5). The IEF effect depends on the light exposure duration and system temperature as shown in Fig. 6.

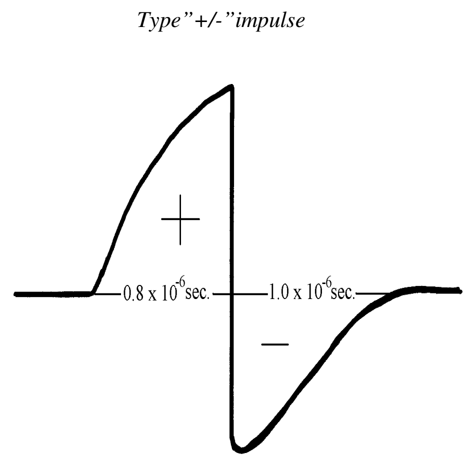

Figure 5. Altering electrical field impulse

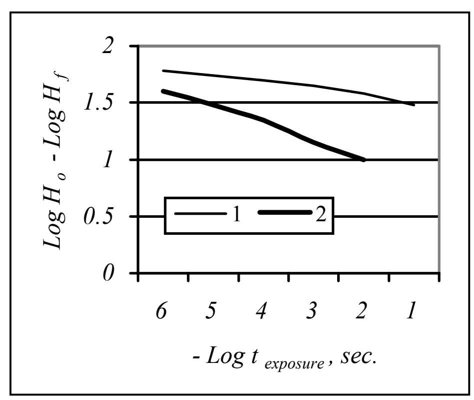

Figure 6. IEF effect at different light exposure.
Film: Orthopanchromatic, cubes, d=0.25µ, E=2.5x10^{-6} V/cm, Impulse form "+/-"
Temperature: 1 - -30°C; 2 - +20°C

The maximal IEF effect was obtained in the case when the duration of light exposure is equal to the duration of electrical field impulse.

The multiple impulse of electrical field was used for the achivement the maximum IEF effect for the continious light exposure – 10^{-1} – 10^{-2}sec (Fig.7).

As it was expected [8], multiple impulse considerably increases IEF effect which in this case slightly depends on the light exposure duration as shown in Fig. 8.

It was also recognized that as the more AgHal grain size so the more IEF effect.

Type"$(+)_n$" impulse

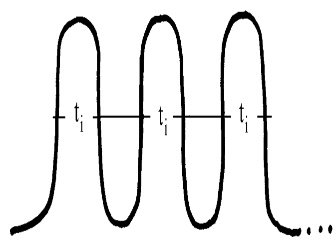

Figure 7. Multiple impulse of the electrical field
$t_l = 0.3x10^{-6}$ sec.

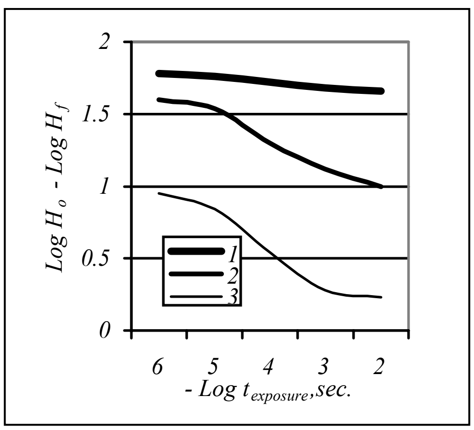

Figure 8. IEF effect at the different light exposure
Film: Orthopanchromatic, cubes, d=0.20μ,
$E=2.5x10^{-6}$ V/cm, 20°C
1 – impulse form " $(+)_n$"
2 - impulse form " +/-"
3 - impulse form " +"

The dependence of IEF effect on the light exposure duration for T-grain emulsion layers at different system temperatures is shown in Fig. 9. So the IEF effect is much higher for large T-grains in comparison with small cubic grains.

It was noticed that the raising of fog level $\Delta D=D_f - D_0$, associated with the IEF effect, is no more than 0.02 – 0.05 and can be minimazed.

The resolution power doesn't practically depend on the IEF effect itself, but strongly depends on the set factors, such as the correct optical contact between electrodes and emulsion layers, optical properties of transparent electrodes (optical transmittance in the range 400-700 nm, refractive index, bulk optical uniformity), spatially homogeneous electrical field and so on.

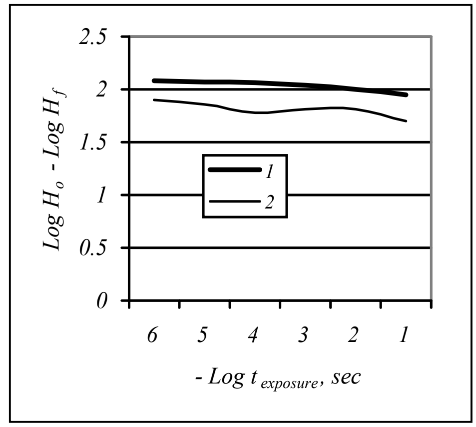

Figure 9. Effect of the impulse electrical field
at the different light exposure time and temperature
Film: Orthochromatic, T-grains
d=1.0μ,, aspect ratio=5.55
1 – -30°C
2 - 20°C

Conclusion

New step of the IEF application for the significant increase of the photographic response of advanced films was done.

The extremely high ΔH value and effective quantum yield cann't be refered the well-known conceptions of the latent image formation theory. In fact, if AgHal grain becomes developable by absorption of 1 or 2 photons so it doesn't mean that the latent image center – development center also contains 1 or 2 silver atoms. The identification of developable center size as a critical quantum numbers isn't incoherent [9].

On the other hand, it's known that accumulation of metalic silver clusters both in the crystall bulk and on the grain surface takes place during precipitation and chemical digestion [10,11]. Besides the photographic sensitivity of emulsions, making at the conditions prevented silver clusters formation (for example at pH≤3.0) is extremely low.

It is reasonable to suppose that metallic silver occurs in the AgHal crystalline lattice in the saturated or supersaturated state [9].

In such situation it is possible to expect that so high IEF effect relate to the following processes:

- ionization and destruction of silver metallic clusters, primordially available in AgHal grains, on exposure to the impulse electrical field
- ionic polarization of AgHal microcrystals in the electrical field
- electron multiplication by the shock ionization.

References

1. Mitchell J.W., *J. Imaging Sci. and Technol.,* **31**, 227 (1983)
2. Tani T., *Photographic Sensitivity,* Oxford University Press, 1995, pg. 229
3. Belloni J., Treguer m., Remita H., De Keyzer R., *Nature,* **23/30** December, 865, 1999
4. Shapiro B.I., *Theoretical Basics of Photographic Process,* Editorial URSS, 2000, pg. 267
5. Rothstein J., *J. Photogr. Sci. and Eng.,* **3,** 255 (1959)
6. Ulanov V.M., J. *Theor. Physics ,* (Russian), **50,** 1044 (1980)
7. Borshevsky B.U., Rjabova R.B., *J., Sci. and Applied Photogr. and cinematogr.,(Russian),* **43,** 44 (1998) ; *J. Phys. Chem.,* (Russian), **41,**2336, (1977)
8. Kolubin A.A., Atamuradov F.H., Pevchev Yu.F., *J. Sci. and Applied Photogr. and Cinematogr.,* (Russian), **17,** 125 (1972)
9. Galashin E.A., Chibisov K.V., *Proc. Academy of Science,* (Russian), **68,** 627 (1968)
10. Mitchell J.W., Mott N.F., *Phil. Mag.,* **2,** 1149 (1957)
11. Belous V.M., Tolstobrov V.I., Chibisov K.V., *Proc. Academy of Science,* (Russian), **244,** 905 (1979)